Forecasts Marine Weather On Java Sea Using Hybrid Methods: TS-ANFIS

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***Abstract*— Indonesia is an archipelago. Consequently, the majorities are working around the sea such as a fisherman. While the number of activities at sea are increasing more accident occurred are rising. This research presents marine weather prediction system using Hybrid Methods TS-ANFIS (Adaptive Neuro Fuzzy Inference System – Time Series) in order to anticipate bad weather and reduce risk. This method use both ocean current and wave height at Java Sea particularly on Gresik in order to forecast ocean current velocity and wave height. Input variables used in this paper are data at (t), an hour before (t-1), and two hours before (t-2) and obtained next hour, next 6 hours, next 12 hours, and next day prediction as output. The results indicate that ocean current speed attain 16.97327 cm/s; 13.22302 cm/s; 10.21107 cm/s; 14.09871 cm/s with mean error is about 0.12993; 1.5758; 1.3182; 0.82613 while wave height reach 0.45554 m; 0.48286 m; 0.46395 m; 0.54571 m with mean error is about 0.0012247; 0.018619; 0.046584; 0.060206. Therefore, it was safe to sailing on 1st January 2016.**

Keywords*— *Marine Weather Prediction, ANFIS Time Series

I. INTRODUCTION

Indonesia is the world largest archipelago. Since it has thousand islands, sailing is the only way to travel from an island to another. Naturally, the majorities who live along the beach work as a fisherman.

Since Joko Widodo launched "tol laut" (maritime highway) as national transportation, the number of shipping and sailing is increasing. Moreover, accidents or incident on a ship such as drowning, ship collision, mishaps, and grounding is on the increase. Irregular weather patterns is a factor cause the accident [1] [2].

This irregular patterns is caused by some factors such as the dynamic periods of east and west Monsoon [3] [4], La Nina and El Nino, Dipole Mode effect, and sea surface temperature. The difference temperature cause different pressure and trigger strong winds. These winds potentially disrupt sea transportation.

Anticipating and reducing the various possibilities or impact that harm people especially fisherman can be done by developing marine weather information. Badan Meteorologi, Klimatologi, dan Geofisika (BMKG), Indonesian Agency for Meteorology, Climatology and Geophysics, is an agency that helps people in charge of weather observers. Unfortunately, due to the prediction, BMKG should predict more accurately since the forecasters analyze subjectively. Therefore, in order to help fisherman designing accurate maritime weather prediction is a must [5][6].

Research on maritime weather prediction using various methods has been widely conducted. The methods were used are short messages service communication [1], Fuzzy Takagi Sugeno [3], Fuzzy Time Series [7], combines Neuro-Fuzzy and Neural Network [8], and Artificial Neural Network [5]. Adaptive Neuro Fuzzy Inference System (ANFIS) Time Series model match for solving forecasting problems [2][6][7][8][9][10][12]. ANFIS is a combination of fuzzy logic that used on predicting weather and artificial neural network that can adapt to atmosphere variables [6][11][13][14].

This paper aim is predicting marine weather (wave height and ocean current velocity) using Adaptive Neuro Fuzzy Inference System Time Series. This research only conducted at Gresik since it is part of Java Sea.

II. THEORETICAL FRAMEWORK

A. Marine Weather

Weather is a phenomenon that happens on Earth's atmosphere currently. Weather is affected by changes in temperature, the duration of solar irradiance, humidity, rainfall, wind, and air pressure that exists all over the earth and occurs in a short time [6][14]. A state of air or phenomena found in the sea that occur at a certain moment and in a short time is called marine weather [2]. In maritime meteorology,

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sea weather is said to be extreme when air temperature> 35^0C, wind speed> 25 knots, wave height> 2.5 meters, heavy rain by lightning and rainfall> 50 mm/day.

B. Weather Influence on Sea

In Indonesia, pressure on sea is higher than on land. This difference causes heavy wind on sea and the wind triggers ocean current and wave height. Therefore, significance weather influences are ocean current speed and wave height [15].

1. Ocean Current
   Ocean current is sea water density movement that vertically or horizontally moves from one place to another
2. Sea Wave
   Sea waves are vibrations that occur at sea surface that direct up and down shape perpendicular to the sea surface and form a sinusoidal curve. The presence of ocean waves is influenced by wind speed. According to safety sail the wave is categorized to 10 scales.

TABLE I. BEAUFORT SCALE [1]

Scale	Categories	Wind speed Va (Knot)	High Wave H (Meter) (Maximum)
0	Calm	0	0
1	Light air	1 – 3	0.1
2	Light breeze	4 – 6	0.2 (0.3)
3	Gentle breeze	7 – 10	0.6 (1.0)
4	Moderate breeze	11 – 16	1.0 (1.5)
5	Fresh breeze	17 – 21	2.0 (2.5)
6	Calm	22 – 27	3.0 (4.0)
7	Light air	28 – 33	4.0 (5.5)
8	Light breeze	34 – 40	5.5 (7.5)
9	Gentle breeze	41 – 47	7.0 (10.0)

C. Adaptive Neuro Fuzzy Inference System

Adaptive Neuro Fuzzy Inference System (ANFIS) is a method that using artificial neural network as an implementation of a fuzzy inference system. ANFIS method has an architecture that functionally resembles to Sugeno fuzzy rule base architecture model [16]. The ANFIS parameter is divided to premise and consequences parameter that can be adapted to the hybrid algorithm [2]. Figure 1 shows ANFIS structure.

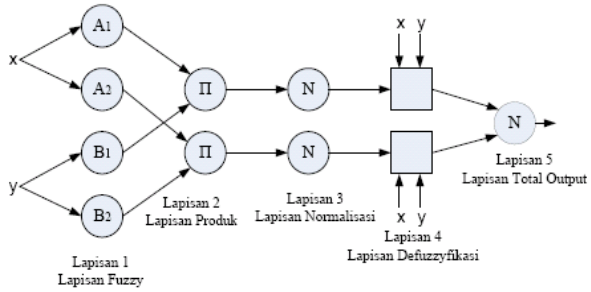

Fig. 1. ANFIS method Structure

- Layer 1: Adaptive points (parameters) may change toward the activation function. Membership functions used in this layer are Bell and Gaussian resulting membership degree.
- Layer 2: All points in this layer are non-adaptive, ie the parameters are fixed. These points multiply every input signal that comes and represent the α-predicate.
- Layer 3: Any non-adaptive point indicating normalized firing strength function is a comparison of the output of the i^{th} term on the previous layer
- Layer 4: Each point of this layer is an adaptive point toward an output with αI is normalized firing strength in layer 3 and parameters at the layer called consequent parameters
- Layer 5: In this layer there is only one fixed point that sum all entries

There are two learning process on (ANFIS), namely epoch and hybrid. Epoch is a forward-backward learning stage while hybrid is forward pass and backward pass ANFIS learning phase [2].

III. METHODOLOGY

A. Reseach Type

This is a cualitative descriptive research. Moreover, it is also an applied research since it apply ANFIS in predicting marine weather as an early warning for fisherman on Java Sea especially at Gresik.

B. Data Collection and Analysis

Amount 8760 used parameters data were obtained by synoptic observation and recorded by Automatic Weather System (AWS) from 1st January to 31st December 2016. These data are accumulated every hour. The data, ocean current speed and wave height, converted into time series and then processed using ANFIS.

There are 3 input variables used in this research i.e. data at (t), an hours before (t-1), and 2 hours before (t-2) for each variable. This system produces ocean current velocity (cm/s) and wave height (m) prediction for next hour, 6 hours later, 12 hours later, and next day.

C. Testing and Evaluation

First test was conducted refers to the time series analysis of the used parameters and solved using MATLAB. The data was separated into two, first used as Ts-ANFIS training data and the rest used as testing data. In order to adress the question well this research follows TS-ANFIS flowchart (figure 2).

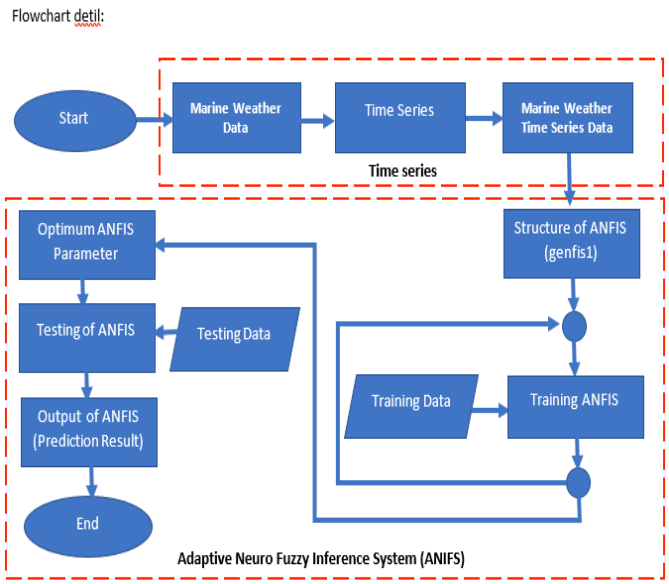

Fig. 2. ANFIS Time Series Flowchart

The following steps are taken referring to the flowchart:

a. Marine weather data are wave height and ocean current velocities hourly for a year.
b. These data converted into time series regarded to input and output variables then separated into training data (75%) and testing data (25%).
c. MATLAB was used in processing time series data using ANFIS time series.
d. ANFIS structures created in early process using genfis1.
e. Input training data into ANFIS training.
f. Optimal ANFIS parameters obtained while smallest error produced by TS-ANFIS shows accurately data.
g. Predictions are obtained when testing data are inputted into ANFIS testing process.

IV. Discussion

Mathematical model use in marine weather prediction is time series. The prediction focuses on ocean current speed and wave height. The prediction presents in time sequences for some periods to help in measuring changes.

Table II presents ocean current speed and wave height data for 1st January 2016. Data is divided into 2 before it is used in TS-ANFIS training process. Seventy five percent data (starting from 1st January to 30th September 2016) used as training data, while the rest 25% (1st October to 31st December 2016) used as testing data. These data should be formed to time series prior to use as input variables (t-2, t-1, and t) and output (t+1, t+6, t+12, and t+24).

TABLE II. Ocean Current Speed and Wave Height

Date (Time)	CuSpd(cm/s)	HTot(m)
1/1/2016 (00.00)	6.54	0.31
1/1/2016 (01.00)	5.65	0.31
1/1/2016 (02.00)	4.76	0.31
1/1/2016 (03.00)	3.88	0.31
1/1/2016 (04.00)	2.99	0.32
1/1/2016 (05.00)	2.1	0.32
1/1/2016 (06.00)	1.21	0.32
1/1/2016 (07.00)	1.01	0.33
1/1/2016 (08.00)	0.81	0.33
1/1/2016 (09.00)	0.61	0.34
1/1/2016 (10.00)	0.41	0.35
1/1/2016 (11.00)	0.21	0.35
1/1/2016 (12.00)	0.02	0.36
1/1/2016 (13.00)	0.16	0.37
1/1/2016 (14.00)	0.3	0.37
1/1/2016 (15.00)	0.45	0.38
1/1/2016 (16.00)	0.6	0.39
1/1/2016 (17.00)	0.74	0.4
1/1/2016 (18.00)	0.89	0.4

A. *Ocean Current Speed Prediction*

Ocean current speed is one of marine weather variable in this research. In this architecture, there are 3 input variables i.e. ocean current speed at t time v(t), an hour before v(t-1), and 2 hours in advance v(t-2). Output variables obtained are speed prediction for next hour v(t+1), next 6 hours v(t+6), next 12 hours v(t+12), and next day v(t+24).

This paper use ANFIS function genfis1 that is "gbellmf" membership function. This paper use 2 membership function is two and 100 iterations. The number of iterations will not affect error values in genfis1 [2]. Results of the test on ocean current speed will be presented in figures below.

Testing result and Fig. 3 to Fig. 6 show that ocean current prediction using TS-ANFIS (green) similar to testing data (blue). This result shows that error value obtained is very small. Table 3 presents ocean current speed prediction and mean error value obtained.

TABLE III. Ocean Current Speed Prediction Result

No	Prediction Time	Amount Data Validated	Ocean Current Prediction Result (cm/s)	Mean Error Value
1	1 hr	2190	16.97327	0.12993
2	6 hrs	2190	13.22302	1.5758
3	12 hrs	2190	10.21107	1.3182
4	24 hrs	2190	14.09871	0.82613

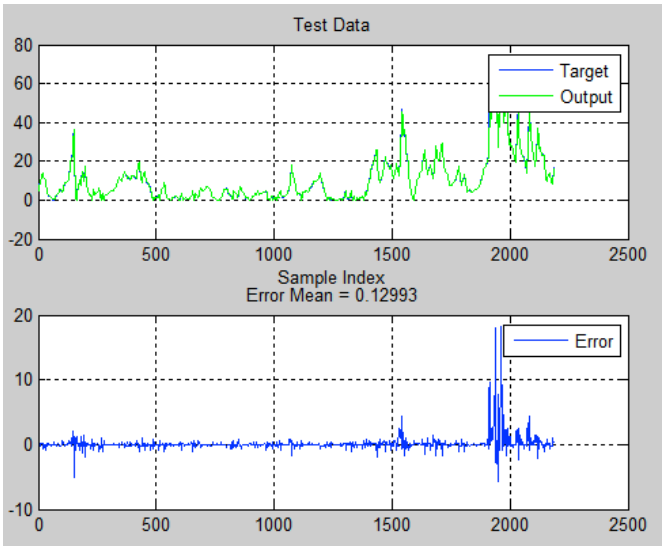

Fig. 3. Next Hour Ocean Current Speed Prediction

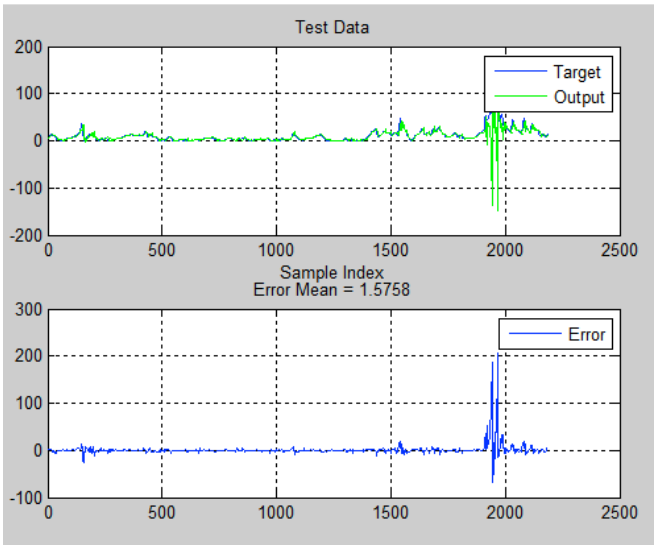

Fig. 4. Next 6 Hours Ocean Current Speed Prediction

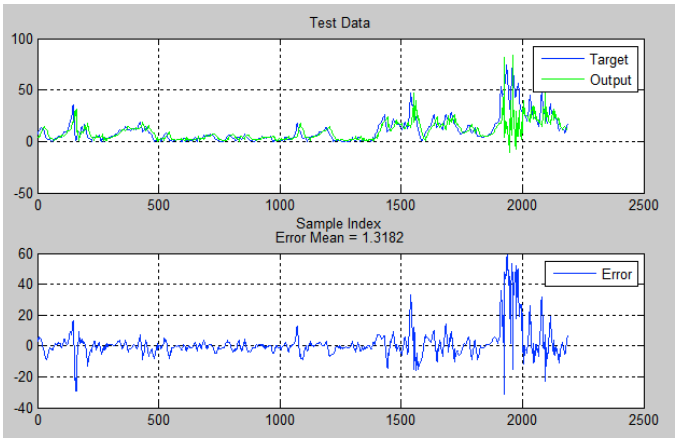

Fig. 5. Next 12 Hours Ocean Current Speed Prediction

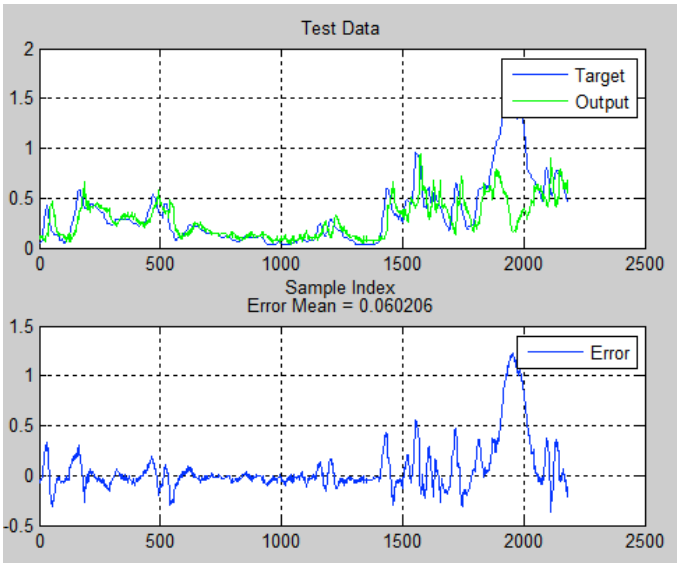

Fig. 6. Next Day Prediction

B. *Wave Height Prediction*

Another marine weather variable is wave height. This architecture use 3 wave heights as input variables, at t h(t), an hour before h(t-1), and 2 hours before h(t-2). Output obtained are prediction for next hour h(t+1), next 6 hours h(t+6), next 12 hours h(t+12), and next day (t+24). TS-ANFIS function, the number of membership function and iteration used similar to ocean current speed prediction. Wave height prediction testing is shown on figures below.

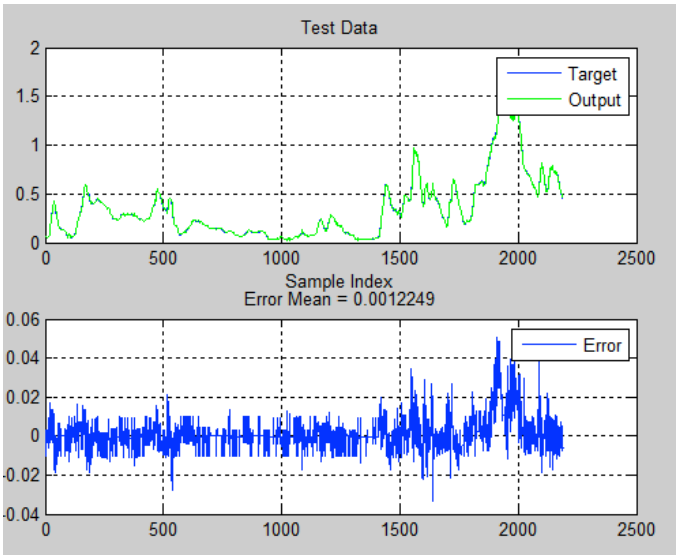

Fig. 7. Next Hour Wave Haeight Prediction

Testing result and Fig. 7 to 10 show that testing data (blue) and TS-ANFIS prediction (green) have no significant different. In other words, wave height prediction using TS-ANFIS produce small mean error value. Wave height prediction and it is error values present in table 4.

TABLE IV. WAVE HEIGHT PREDICTION

No	Prediction Time	Amount Data Validated	Wave Height Prediction Result (m)	Mean Error Value
1	1 hour	2190	0.45554	0.0012247
2	6 hours	2190	0.48286	0.018619
3	12 hours	2190	0.46395	0.046584
4	24 hours	2190	0.54571	0.060206

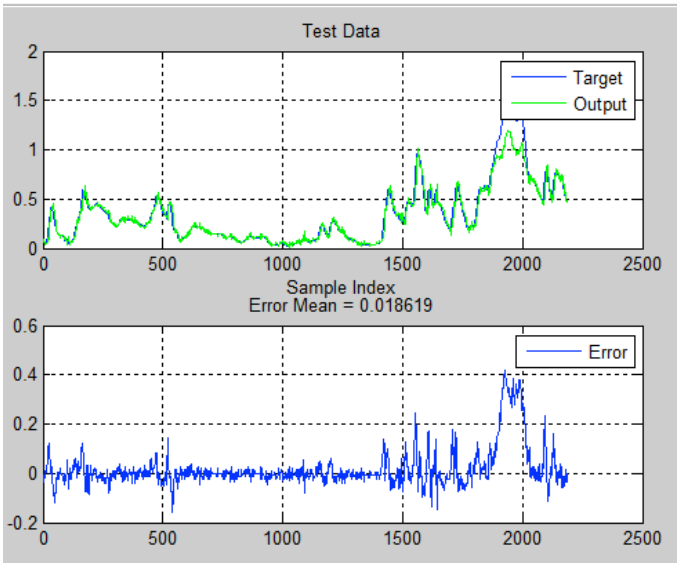

Fig. 8. Next 6 Hours Wave Height Prediction

Fig. 9. Next 12 Hours Wave Height Prediction

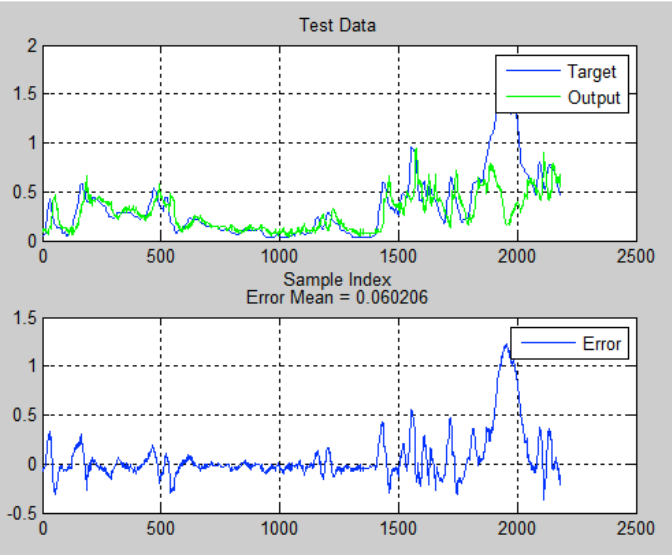

Fig. 10. Next Day Wave Height Prediction

C. *Sailing Feasibilty Analysis*

Ocean current speed prediction for next hours, 6 hours, 12 hours, and 24 hours are TS-ANFIS prediction shows that ocean current speed attain 16.97327 cm/s; 13.22302 cm/s; 10.21107 cm/s; 14.09871 cm/s while wave height reach 0.45554 m; 0.48286 m; 0.46395 m; 0.54571 m. Therefore, these numbers indicate that on 1st January 2017 Java Sea is safe for sailing. However, fisherman should be careful since ocean current speed at 6 and 12 next hour have bigger mean error value.

V. CONCLUSSION

The Marine weather prediction using ANFIS Time Series show that:

a. Smallest error mean resulted on TS ANFIS training data process are 0.12993; 1.5758; 1.3182; 0.82613 for ocean current speed and 0.0012247; 0.018619; 0.046584; 0.060206 for wave height for an hour, 6 hours, 12 hours, and 24 hours later respectively.

b. The Prediction presents that ocean current speed attain 16.97327 cm/s; 13.22302 cm/s; 10.21107 cm/s; 14.09871 cm/s and wave height reach 0.45554 m; 0.48286 m; 0.46395 m; 0.54571 m for an hour, 6 hours, 12 hours, and 24 hours later. It follows that, save to sail on Java Sea at 1st January 2017.

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